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14. ABSTRACT A novel form of sandwich construction is disclosed. The lattice core sandwich construction comprises of elongate lattice cells in side-by-side abutment, to present common, lengthwise flat sides that have facesheets co-cured thereto without any secondary bonding. Each lattice cell is formed by wrapping, in alternate patterns, fiber-reinforced, composite bands around commonly-shaped mandrels. Oppositely disposed face sheets are placed against flat sides and the construction co-cured. After co-curing, the mandrels are removed.					
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United States Patent [19]**Ray et al.**[11] **Patent Number:** **5,474,632**[45] **Date of Patent:** **Dec. 12, 1995**[54] **METHOD OF MAKING A LATTICE CORE SANDWICH CONSTRUCTION**[75] **Inventors:** **Hemen Ray**, Perkasic, Pa.; **Lee W. Gause**, Oakton, Va.[73] **Assignee:** **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

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[21] **Appl. No.:** **277,400**[22] **Filed:** **Jul. 19, 1994****Related U.S. Application Data**

[62] Division of Ser. No. 82,067, Jun. 23, 1993, Pat. No. 5,424, 113.

[51] **Int. Cl.⁶** **B32B 3/12**[52] **U.S. Cl.** **156/173; 156/175; 156/189; 156/191; 156/195; 156/292; 428/116**[58] **Field of Search** **156/184, 189, 156/292, 191, 195, 173, 175; 428/116**[56] **References Cited****U.S. PATENT DOCUMENTS**

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Primary Examiner—Jeff H. Aftergut*Attorney, Agent, or Firm*—James V. Tura; Susan E. Verona[57] **ABSTRACT**

A novel form of sandwich construction is disclosed. The lattice core sandwich construction comprises of elongate lattice cells in side-by-side abutment, to present common, lengthwise flat sides that have facesheets co-cured thereto without any secondary bonding. Each lattice cell is formed by wrapping, in alternate patterns, fiber-reinforced, composite bands around commonly-shaped mandrels. Oppositely disposed face sheets are placed against flat sides and the construction co-cured. After co-curing, the mandrels are removed.

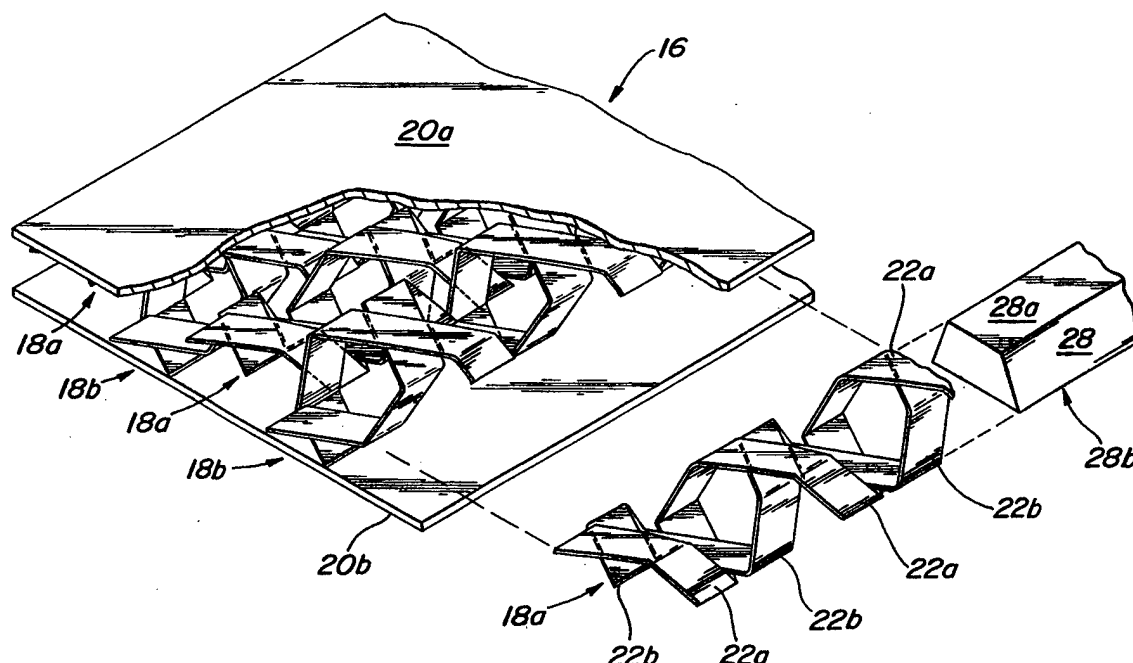
3 Claims, 3 Drawing Sheets11408
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FIG. 1
PRIOR ART

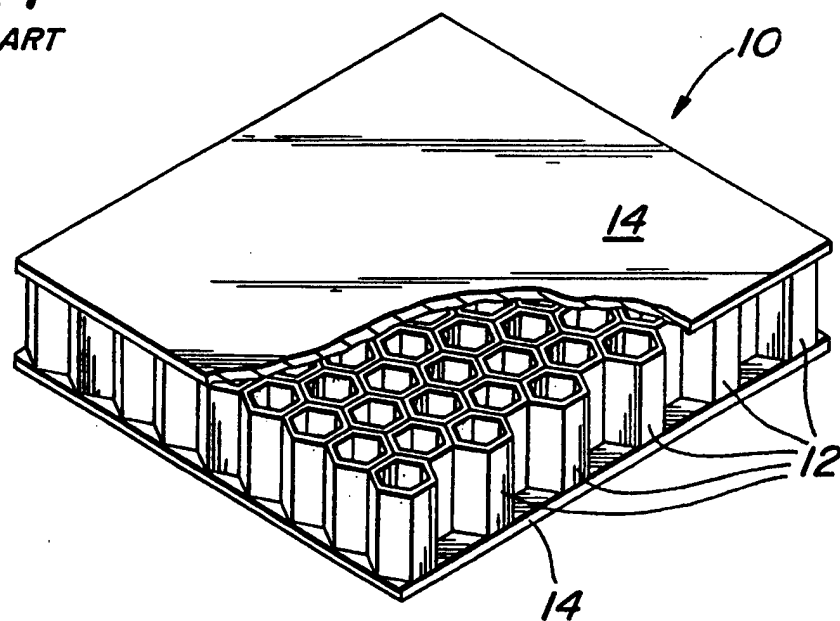


FIG. 3

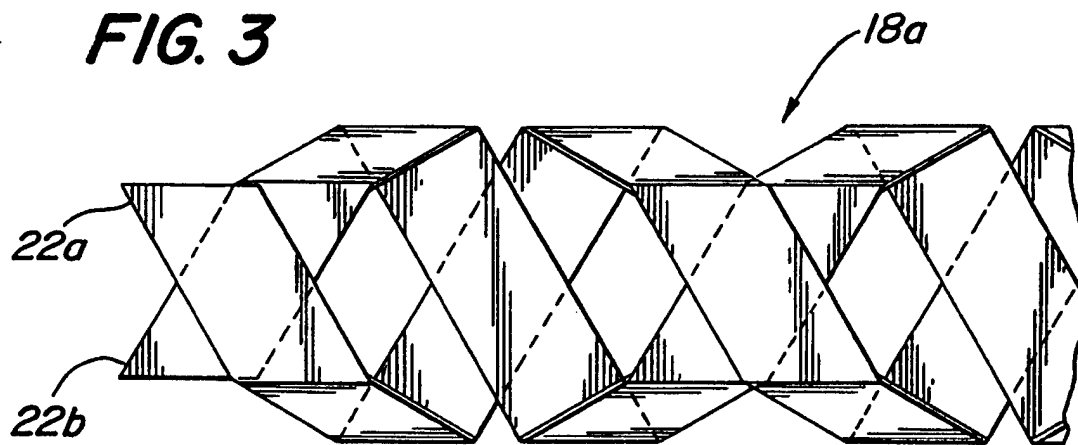
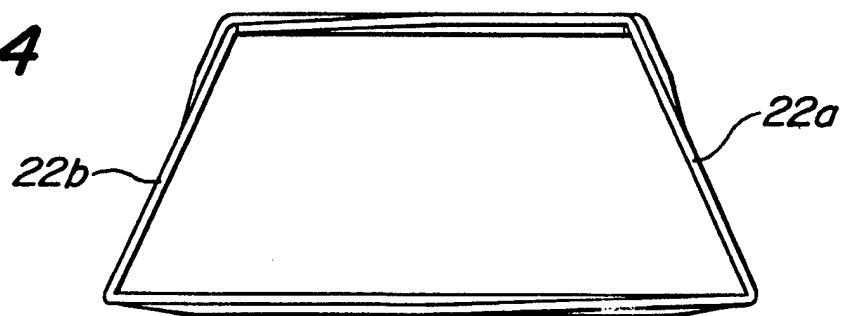


FIG. 4



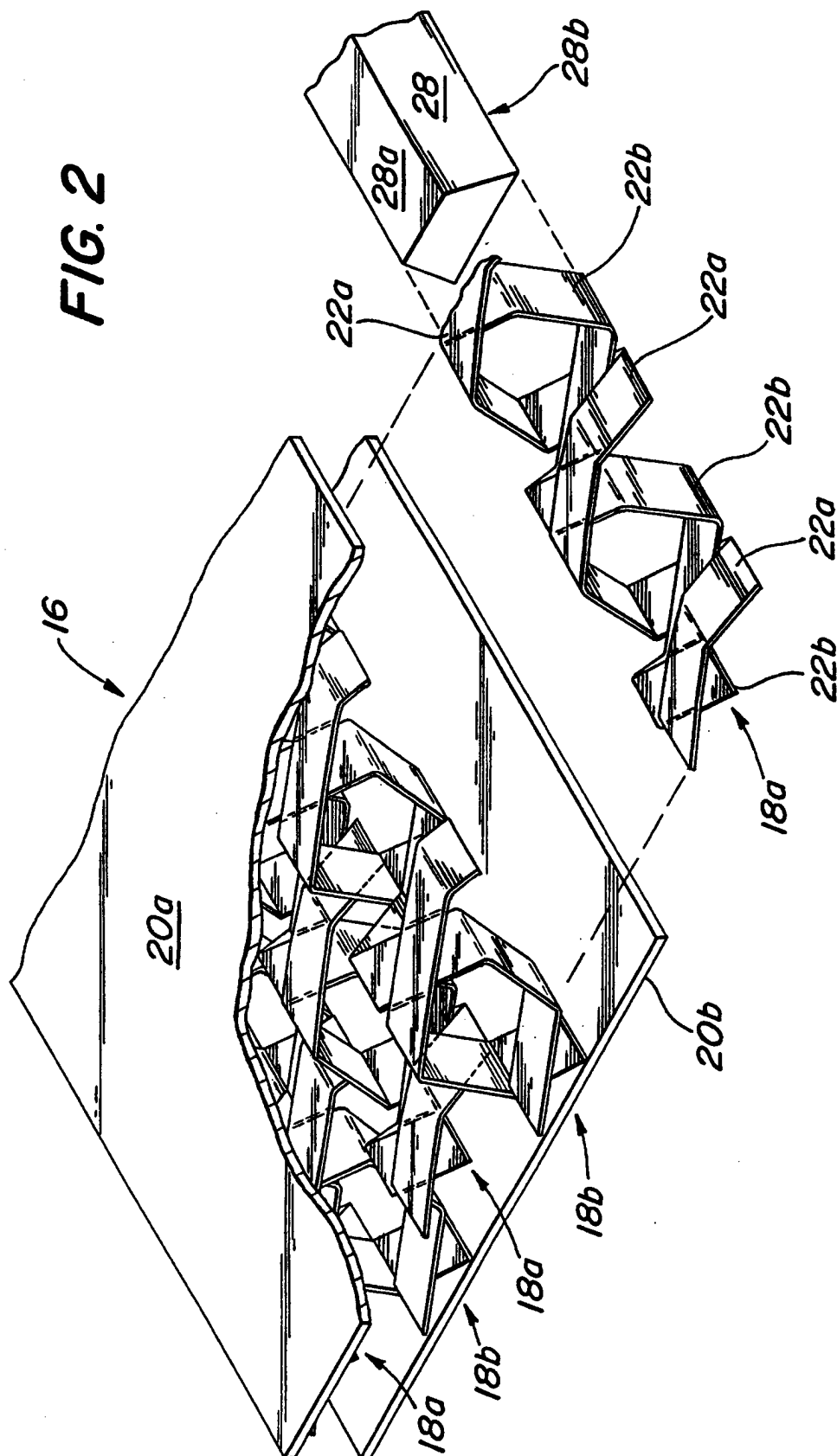


FIG. 5

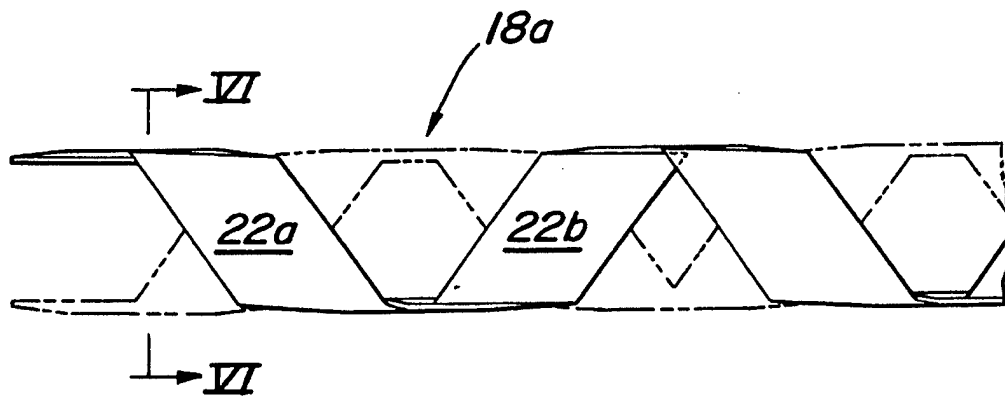
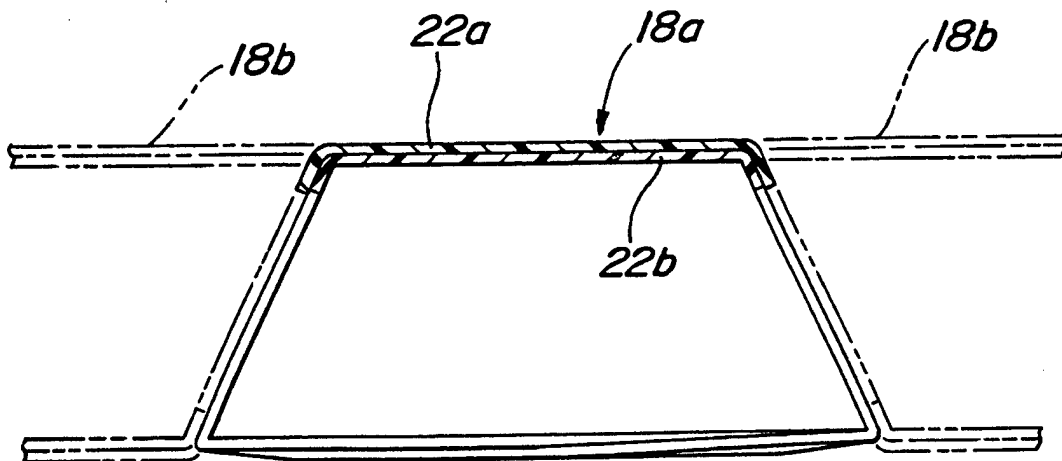


FIG. 6



METHOD OF MAKING A LATTICE CORE SANDWICH CONSTRUCTION

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor. This application is a division of application Ser. No. 08/082,067, filed Jun. 23, 1993, U.S. Pat. No. 5,424,113.

BACKGROUND OF THE INVENTION

The present invention relates generally to sandwich constructions suitable for use in structural and non-structural members, and more particularly to sandwich constructions of low-density cores secured between thin-gauge, high-strength face sheets for use in a wide range of military, industrial and commercial components.

Sandwich constructions are finding broad application as structural and non-structural members in boats, aircraft, furniture, refrigerators, and other items requiring high strength, lightweight materials. They typically include face sheets bonded to either side of a low density core. The sheets are made of such materials as metals, plastic, or composite fiber glass laminates for rigidity and strength. Among the various core materials, are rigid plastic foams and honeycombs made from layers of corrugated metal sheets or expanded layers of resin-impregnated plastic sheets.

In airplane design the need for weight efficiency and aerodynamically smooth surfaces under high stress levels has stimulated use of sandwich construction as a possible substitute for the conventional sheet-stringer construction. Notwithstanding the superior weight-efficiency of the sandwich constructions, their general acceptance for critical applications has lagged behind theoretical development primarily because of maintenance problems experienced in service. Honeycomb core sandwich constructions are considered to be among the most weight-efficient but, they have a tendency to retain moisture which may become entrapped due to ineffective edge seals, damage to the face sheets or unbonding of face sheets from the core. This may degrade the structural integrity and lead to extensive corrosion and premature failure of components. Experience has shown a significant frequency of repairs on sandwich structures or sandwich structure part replacements which are very time-consuming and expensive.

SUMMARY OF THE INVENTION

Accordingly, an object of the present invention is to provide a sandwich construction having a high strength-to-weight efficiency suitable for a broad variety of military, industrial and commercial applications.

Another object is to provide a low-density core sandwich construction in which corrosion and degradation of structural integrity due to retention of moisture is substantially eliminated.

Another object is to provide a sandwich construction in which unbonding of face sheets from the core is substantially reduced or eliminated when heat, pressure or vacuum is applied for purposes of repair.

Still another object is to provide a sandwich construction having a flexible core with structural discontinuities for improved tolerance for damage.

A further object is to provide a method of fabricating a low-density core sandwich construction in a single curing process.

A still further object is to provide a sandwich construction having a core with passageways for arresting cracks developed during use or upon impact.

These and other objects of the invention are achieved in a sandwich construction comprising a core of elongate lattice cells in side-by-side abutment and secured between two face sheets. Each lattice cell is defined by an openwork structure of crisscrossed bands of stiff material helically formed around the longitudinal axis thereof. A cell is formed by wrapping two bands in opposite directions around a mandrel of lengthwise uniform cross section and opposite flat sides for contiguously interfacing complimentary sides of adjacent cells and the face sheets. With the mandrels in place, the cells are then secured between the face sheets and cured in a single curing process after which the mandrels are removed.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the invention will become apparent from the following detailed description taken in conjunction with the accompanied drawings wherein:

FIG. 1 represents a perspective view, with the upper face sheet partially cutaway, of a prior art honeycomb core sandwich construction;

FIG. 2 represents a perspective view, with the upper face sheet partially cutaway, of a lattice core sandwich construction according to the invention with a single cell extended from the construction to more clearly show the relationship of the mandrel to the cell;

FIG. 3 is a top view of a lattice cell of crisscrossed bands of material helically wound according to the invention around a trapezoidal mandrel (not shown);

FIG. 4 is an end view of the cell of FIG. 3;

FIG. 5 is a side view of a single cell showing a single band wrapping; and

FIG. 6 is a cross-sectional view of a single wrapping taken along lines VI—VI of FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings wherein like referenced characters designate like or corresponding components throughout the several views, there is shown in FIG. 1 a typical prior art honeycomb core sandwich construction 10 having a low density core consisting of hexagonal cells 12 bonded at their ends to face sheets 14. However, under stress the face sheets may crack or separate from the cell ends permitting moisture to accumulate and with time cause the core to increase in weight and corrode. The usual procedure for repair entails resealing the cell ends by applying an adhesive and applying heat and pressure (or vacuum) to the external surfaces of the facing sheets. This is unreliable and sometimes causes further unbonding of face sheets and core.

Referring to the inventive embodiment of FIGS. 2 through 4, there is shown a lattice core sandwich construction 16 of elongate cells 18a and 18b in side-by-side alignment between face sheets 20a and 20b. Each cell 18a or 18b defines in transverse cross section and isosceles trapezoid formed by stiff bands 22a and 22b of fiber-reinforced composite helically wound in opposite directions

along a longitudinal axis. Bands **22a** and **22b** crisscross at intervals on the unequal sides of the cells and are attached to face sheets **20a** and **20b** by co-curing. The unequal sides of cells **18a** are inverted with respect to those of cells **18b** to provide contiguous contact of interfacing equal sides of adjacent cells. Thus, it can be seen that the openwork lattice provides communication between cells for preventing stagnation of any accumulated moisture and thereby minimizing corrosion. In addition, the various angles of bands **22a** and **22b** formed relative to the interfacing planes of facing sheets **20a** and **20b** and to the sides of cells **18a** and **18b**, provide a sandwich construction of comparable strength.

The method of fabricating the above-described lattice core sandwich construction **16** can be explained with reference to FIGS. 2 through 6. Each cell **18a** and **18b** is formed by wrapping bands **22a** and **22b** around and along the length of an elongate mandrel **28** of isosceles trapezoidal transverse cross section. In the illustrated embodiment, the bands are a fiber-reinforced, resin-impregnated composite and the mandrel is solid plastic type material, such as TFE or other similar materials, to facilitate its removal after curing. Bands **22a** and **22b** are helically wrapped such that they crisscross on unequal opposite sides **28a** and **28b** of mandrel **28** and leave open spaces therein for moisture communication. The wrapped mandrels are then placed, alternately inverted, in side-by-side abutment between fiber-reinforced resinous composite face sheets **20a** and **20b** and co-cured without any secondary bonding to the exposed bands of cells **18a** and **18b**. At this point in the operation, mandrels **28** are removed (see FIG. 2.)

Other acceptable tooling materials and mandrel configurations are contemplated depending on the application, core and face sheet materials, and bonding process. Of course, the composition of the materials and the shape of the mandrels will influence the structural strength and integrity of the finished lattice core sandwich construction. In some applications, the mandrel may be inflatable to incorporate complex shapes. Furthermore, the lattice cells may be fabricated from bands of composites or metal and attached to the face sheets by secondary bonding.

Some of the many advantages of the invention should now be readily apparent. For example, the lattice core Sandwich construction provides passageways from cell to cell allowing moisture to drain, reducing the tendency for corrosion. The lattice core provides flexibility and discontinuity for improved tolerance for damage. Cracks developed due to impact are arrested. The lattice core sandwich

construction is cost effective because it is especially suitable for resin transfer-molding woven fabrics on reusable solid or inflatable mandrels. The tendency for unbonding face sheets from the core due to heat and pressure (or vacuum) during repairs is also substantially reduced or eliminated.

It will be understood that various changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principles and scope of the invention as expressed in the appended claims.

What we claim is:

1. A method of fabricating a lattice core sandwich construction, comprising the steps of:

providing first and second pluralities of bands of curable material;

providing a plurality of mandrels, each having a uniform transverse cross-section in a shape of an isosceles trapezoid with two parallel sides of unequal length and two non-parallel sides of equal length;

helically wrapping each band of the first plurality in one direction around each one of the plurality of mandrels, leaving a plurality of unwrapped open spaces on each one of the mandrels;

helically wrapping each band of the second plurality in the opposite direction around each one of the plurality of mandrels so that the bands of the second plurality crisscross the bands of the first plurality on the sides of unequal length, leaving a plurality of unwrapped open spaces on each of the mandrels;

abutting said wrapped mandrels alternately inverted side-by-side along their equal-lengthed sides along the entire surfaces thereof;

securing at least one face sheet of curable material to one of the parallel sides of the abutted wrapped mandrels; co-curing the bands and face sheet; and removing the mandrels.

2. The method according to claim 1, wherein:

said bands and said face sheet comprise fiber-reinforced resinous composites.

3. The method according to claim 1, further comprising the step of securing a second face sheet of curable material to the other parallel side of the wrapped mandrels.

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